FUTURE FISHERIES IMPROVEMENT PROGRAM
GRANT APPLICATION

(please fill in the highlighted areas)

I. APPLICANT INFORMATION

A. Applicant Name: Matt Jaeger

B. Mailing Address: 730 ½ N. Montana

C. City: Dillon State: MT Zip: 59725

Telephone: 406-683-9310 E-mail: mattjaeger@mt.gov

D. Contact Person: Matt Jaeger

Address if different from Applicant:

City: State: Zip:

Telephone: E-mail:

E. Landowner and/or Lessee Name (if other than Applicant): Red Rock Lakes National Wildlife Refuge c/o Bill West

Mailing Address: 27650 B South Valley Road

City: Lima State: MT Zip: 59739

Telephone: 406-276-3536 ext 103 E-mail: bill_west@fws.gov

II. PROJECT INFORMATION*

A. Project Name: Elk Springs Creek Arctic grayling spawning habitat restoration

River, stream, or lake: Elk Springs Creek

Location: Township: 15 N Range: 40 E Section: 6

Latitude: 44.64952 Longitude: -111.65020 *within project (decimal degrees)*

County: Beaverhead

B. Purpose of Project:

Restoration of Arctic grayling spawning habitat to Elk Springs Creek.

C. Brief Project Description:

Elk Springs Creek in the Centennial Valley historically supported one of Montana's most prolific Arctic grayling spawning populations. Between 1898 and 1908 millions of eggs were taken from thousands of grayling by the U.S. Fish Commission to create new grayling fisheries and fuel the first Montana Arctic grayling conservation effort; however, the spawning habitat that supported this population was subsequently serially fragmented and degraded. Elk Springs Creek was diverted from its historic channel, which flowed directly into Upper Red Rock Lake, into a shallow wetland marsh called Swan Lake by duck hunters in 1908. The prolific Elk Springs Creek Arctic grayling spawning run crashed in 1909, although it is unclear if it was caused by the aforementioned diversion of Elk Springs Creek or the simultaneous closure of Lima Dam at the lower end of the Centennial Valley. The stream was further fragmented and its spawning habitat degraded by an impoundment constructed in 1953 (Macdonald Pond) and an undersized and perched culvert that backwatered several hundred feet of stream installed during construction of Culver Road in 1965. The historically used spawning reach was further degraded by channelization occurring in 1955. Spawning Arctic grayling have resultantly been extirpated from Elk Springs Creek for the past century.

Restoration of the Elk Springs Creek watershed is presently being undertaken to restore spawning habitat to Elk Springs Creek and the Centennial Valley Arctic grayling population. MacDonald Pond was drained in 2009 and the undersized culvert on Culver Road removed in 2011. Elk Springs Creek will be restored to its historic channel alignment and inlet such that it flows directly into Upper Red Rock Lake in 2016, thereby providing full connectivity and fish passage.

This proposal seeks funding to restore spawning habitat in the historically used 0.3 mile long spawning reach of Elk Springs Creek by 1) removing sediment deposited by MacDonald Pond, 2) importing spawning gravels where needed, and 3) restoring natural channel dimensions and sinuosity capable of maintaining self-sustaining Arctic grayling spawning habitat and preventing deposition of fine sediment. The dimensions and hydraulics of the channel that naturally colonized the post-impoundment lake bed do not adequately mobilize and sort gravels and flush lake-deposited fine sediment and further narrowing to dimensions capable of doing so is unlikely without mechanical restoration (Attachment A). Augmenting the stable 9 cfs discharge of Elk Springs Creek with periodic sediment flushing and habitat maintenance flows delivered from an adjacent impoundment were explored but deemed infeasible; flows of about 175 cfs would be required to mobilize gravels and effectively flush fine sediment given the present channel dimensions (Attachment A). Therefore, excavation of fine sediment and mechanical narrowing of the channel by 50 to 80% was designed to restore self-maintaining high quality spawning habitat (Attachment B). Spawning gravels will be added to sections of stream as needed to meet design specifications that optimize overall quality of grayling spawning habitat (i.e., less than 10% fines and 20-60 cm/s velocity). The stable hydrology (all stream flow is provided by springs directly above the project area), calculated sediment mobility at designed channel dimensions, and absence of sediment sources ensure that created spawning areas and imported gravel will remain in place and be self-maintained through time. New stream banks will be constructed from rolled locally salvaged wetland sod mats and the excavated fine sediment deposited behind the new bank lines. Sinuosity will also be restored to this channelized reach creating an additional 338 feet of stream.

Once completed this project will bolster abundances and improve long-term population viability of Centennial Valley Arctic grayling by adding a second major spawning tributary that is hydrologically disconnected from Red Rock Creek, thereby dampening the effects of environmental stochasticity. This project will also provide a new and unique angling experience for wild native Montana Arctic grayling on public lands.

D. Length of stream or size of lake that will be treated: 0.3 miles by this funding proposal, 7 miles overall.

E. Project Budget:

Grant Request (Dollars): $ 45,000

Contribution by Applicant (Dollars): $ 21,713 In-kind $

(salaries of government employees are not considered as matching contributions)

Contribution from other Sources (Dollars): $ 39,995 In-kind $

(attach verification - See page 2 budget template)

Total Project Cost: $ 106,708

F. Attach itemized (line item) budget – see template

G. Attach specific project plans, detailed sketches, plan views, photographs, maps, evidence of landowner consent, evidence of public support and fish biologist support, and/or other information necessary to evaluate the merits of the project. If project involves water leasing or water salvage complete supplemental questionnaire (fwp.mt.gov/habitat/futurefisheries/supplement2.doc).

H. Attach land management and maintenance plans that will ensure protection of the reclaimed area.

III. PROJECT BENEFITS*

A. What species of fish will benefit from this project?:

Arctic grayling

B. How will the project protect or enhance wild fish habitat?:

This project will reconnect and provide spawning habitat in Elk Springs Creek for the Centennial Valley Arctic grayling population by restoring natural sinuosity, dimensions, and spawning gravels to a channelized reach of stream overlain by reservoir sediment. Spawning habitat in Elk Springs Creek would improve, benefiting the Centennial Valley Arctic grayling population.

The proposed project is part of broader restoration of the Elk Springs Creek watershed. Other projects, not a part of this application, have removed an impoundment, will replace an undersized and perched culvert with a bridge, and re-route a channelized and diverted reach of stream directly into Upper Red Rock Lake. Collectively, these projects are expected to improve the Arctic grayling population by restoring connectivity, creating suitable spawning areas, and producing self-maintaining, healthy stream function.

C. Will the project improve fish populations and/or fishing? To what extent?:

Yes. Most Arctic grayling spawning in the Centennial Valley presently occurs in a single stream (Red Rock Creek). This project will restore spawning habitat to a second historically heavily used spawning tributary, thereby increasing population size, dampening the effects of environmental stochasticity and dramatically improving long-term population resiliency. The benefits to population viability of restoring spawning to Elk Springs Creek are magnified because it is a spring system that is hydrologically disconnected from the runoff driven Red Rock Creek, which allows cool stable flows in years that Red Rock Creek may experience catastrophically high or low flows during spawning periods.

The entire project area occurs on public land that is open to angling with the exception of seasonal closures.

D. Will the project increase public fishing opportunity for wild fish and, if so, how?:

Yes. Because the entire project occurs on public lands that are open to angling there will be a direct increase in public angling opportunity created by this project. Connectivity between Elk Springs Creek and Upper Red Rock Lake has been fragmented and the quality and quantity of spawning habitat reduced, which has cumulatively precluded use by wild Arctic grayling for the past 100 years. By restoring connectivity and high quality self-sustaining spawning habitat a spawning run of Arctic grayling will be re-established, which will provide an angling opportunity for a wild native fish that hasn’t existed for over a century. However, we do anticipate placing a seasonal angling closure on this stream to prevent trampling of incubating embryos.

E. The project agreement includes a 20-year maintenance commitment. Please discuss your ability to meet this commitment.

Because this project occurs on a spring system we anticipate it will be inherently stable and require little maintenance. Fish connectivity and spawning habitat quantity and quality will be annually monitored by the FWS and FWP for the next 20 years as part of their collaborative adaptive management plan (Attachment C). Any required maintenance will occur in accordance with that plan. There are no existing diversions or riparian grazing permitted along the entirety of Elk Springs Creek in accordance with the Red Rock Lakes National Wildlife Refuge Comprehensive Conservation Plan (http://www.fws.gov/mountain-prairie/refuges/rrl.php), which further reduces the likelihood of incurring future maintenance needs.

F. What was the cause of habitat degradation in the area of this project and how will the project correct the cause?:

Habitat degradation was caused by fragmentation, degradation, channelization, and impoundment of the Elk Springs Creek watershed. Elk Springs Creek was diverted from its historic channel, which flowed directly into Upper Red Rock Lake, into a shallow wetland marsh called Swan Lake by duck hunters in 1908 and its prolific Arctic grayling spawning run crashed in 1909. The stream was fragmented and its spawning habitat degraded by an impoundment constructed in 1953 (MacDonald Pond) and an undersized and perched culvert that backwatered several hundred feet of stream installed during construction of Culver Road in 1965. The historically used spawning reach was further degraded by channelization occurring in 1955.

Habitat restoration will occur by restoring connectivity and spawning habitat to Elk Springs Creek. This project will restore habitat in the historically used spawning reach by 1) removing sediment deposited by MacDonald Pond, 2) importing spawning gravels where needed, and 3) restoring natural dimensions and sinuosity capable of mobilizing fine sediment and maintaining self-sustaining Arctic grayling spawning habitat.

Additional restoration projects that are not a part of this funding proposal include draining Macdonald Pond in 2009 to restore stream habitat, removing the undersized and perched culvert on Culver Road in 2011, installing a bridge spanning the width of the channel and restoring lower Elk Springs Creek to its historic channel such that it flows directly into Upper Red Rock Lake in 2016, thereby providing full connectivity, fish passage, and spawning habitat.

G. What public benefits will be realized from this project?:

The primary project benefit will be conservation of native Arctic grayling through improved population resiliency associated with restoration of the historically most heavily used spawning tributary in the Centennial Valley. This project will also provide a new and unique angling experience for wild Arctic grayling.

H. Will the project interfere with water or property rights of adjacent landowners? (explain):

No. All land and water rights are owned by and a part of the U.S. Fish and Wildlife Service's Red Rock Lakes National Wildlife Refuge, which is managed specifically for conservation of native species including Arctic grayling.

I. Will the project result in the development of commercial recreational use on the site?: (explain):

There is presently some outfitted angling that occurs in the Centennial Valley. Restoration of this population of Arctic grayling may result in a minor increase in commercial recreational use.

J. Is this project associated with the reclamation of past mining activity?:

No.

Each approved project sponsor must enter into a written agreement with the Department specifying terms and duration of the project.

IV. AUTHORIZING STATEMENT

I (we) hereby declare that the information and all statements to this application are true, complete, and accurate to the best of my (our) knowledge and that the project or activity complies with rules of the Future Fisheries Improvement Program.

Applicant Signature: Matthew Jaeger Date: 10 May 2016

Sponsor (if applicable):

***Highlighted boxes will automatically expand.**

Mail To: **Montana Fish, Wildlife & Parks**
Habitat Protection Bureau
PO Box 200701
Helena, MT 59620-0701

E-mail To: **Michelle McGree**
mmcgree@mt.gov
(electronic submissions MUST be signed)

Incomplete or late applications will be rejected and returned to applicant.
Applications may be rejected if this form is modified.

*****Applications may be submitted at anytime, but must be signed and received by the Future Fisheries Program office in Helena <u>before</u> December 1 and June 1 of each year to be considered for the subsequent funding period.*****

BUDGET TEMPLATE SHEET FOR FUTURE FISHERIES PROGRAM APPLICATIONS

Both tables must be completed or the application will be returned

WORK ITEMS (ITEMIZE BY CATEGORY)	NUMBER OF UNITS	UNIT DESCRIPTION*	COST/UNIT	TOTAL COST	CONTRIBUTIONS			
					FUTURE FISHERIES REQUEST	IN-KIND SERVICES**	IN-KIND CASH	TOTAL
Personnel*								
Survey	40	hr	$90.00	$ 3,600.00	-		3,600.00	$ 3,600.00
Design	50	hr	$90.00	$ 4,500.00	-		4,500.00	$ 4,500.00
Engineering		hr	$90.00	$ -	-			$ -
Permitting	27	hr	$90.00	$ 2,430.00	-		2,430.00	$ 2,430.00
Oversight	150	hr	$75.00	$ 11,250.00			11,250.00	$ 11,250.00
				$ -				$ -
			Sub-Total	$ 21,780.00	$ -	$ -	$ 21,780.00	$ 21,780.00
Travel								
Mileage	1200	mi	$0.56	$ 672.00			672.00	$ 672.00
Per diem	60	days	$50.00	$ 3,000.00			3,000.00	$ 3,000.00
			Sub-Total	$ 3,672.00	$ -	$ -	$ 3,672.00	$ 3,672.00
Construction Materials****								
native wetland grass mix	8	lb	$72.00	$ 576.00			576.00	$ 576.00
native upland grass mix	60	lb	$11.50	$ 690.00			690.00	$ 690.00
washed spawning gravels	120	cu yd	$47.00	$ 5,640.00			5,640.00	$ 5,640.00
				$ -				$ -
				$ -				$ -
				$ -				$ -
				$ -				$ -
				$ -				$ -
				$ -				$ -
			Sub-Total	$ 6,906.00	$ -	$ -	$ 6,906.00	$ 6,906.00
Equipment and Labor								
Excavators (2)	260	hr	$125.00	$ 32,500.00	32,500.00			$ 32,500.00
Track Trucks (2)	220	hr	$120.00	$ 26,400.00	5,300.00		21,100.00	$ 26,400.00
D6 Dozer	20	hr	$105.00	$ 2,100.00	2,100.00			$ 2,100.00
10- wheel truck	20	hr	$95.00	$ 1,900.00	1,900.00			$ 1,900.00
Labor- manual	80	hr	$40.00	$ 3,200.00	3,200.00			$ 3,200.00
				$ -				$ -
			Sub-Total	$ 66,100.00	$ 45,000.00	$ -	$ 21,100.00	$ 66,100.00
Mobilization								
excavators	30	hr	$110.00	$ 3,300.00			3,300.00	$ 3,300.00
trac-trucks	30	hr	$110.00	$ 3,300.00			3,300.00	$ 3,300.00
dozer	15	hr	$110.00	$ 1,650.00			1,650.00	$ 1,650.00
				$ -				$ -

BUDGET TEMPLATE SHEET FOR FUTURE FISHERIES PROGRAM APPLICATIONS

			Sub-Total	$ 8,250.00	$ -	$ -	$ 8,250.00	$ 8,250.00
			TOTALS	$ 106,708.00	$ 45,000.00	$ -	$ 61,708.00	$ 106,708.00

*Units = feet, hours, inches, etc. Please do not use lump sum.

**Can include in-kind materials. Justification for in-kind labor (e.g. hourly rates used for calculations). Describe here or in text.

Reminder: Government salaries cannot be used as in-kind match

***The Review Panel suggests that design and oversight costs associated with a proposed project not exceed 15% of the total project budget. If design and oversight costs are in excess of 15%, applications must include a minimum of two competitive bids for the cost of undertaking the project

****The Review Panel recommends a maximum fencing cost of $1.50 per foot

MATCHING CONTRIBUTIONS (do not include requested funds)

CONTRIBUTOR	IN-KIND SERVICE	IN-KIND CASH	TOTAL	Secured? (Y/N)
MT FWP 2014- Geo. Recon.	$ -	$ 1,800.00	$ 1,800.00	Y
USFWS 2014 Geo. Recon.	$ -	$ 2,095.00	$ 2,095.00	Y
MT FWP 2015- Survey	$ -	$ 1,750.00	$ 1,750.00	Y
USFWS 2015- Design	$ -	$ 2,450.00	$ 2,450.00	Y
USFWS 2016- bridge/ restoration permitting/funding/admin.	$ -	$ 2,450.00	$ 2,450.00	Y
USFWS-Fisheries	$ -	$ 10,000.00	$ 10,000.00	N
Red Rock Lakes National Wildlife Refuge	$ -	$ 10,000.00	$ 10,000.00	N
FWP State Wildlife Grant	$ -	$ 18,163.00	$ 18,163.00	N
George Grant Trout Unlimited	$ -	$ 5,000.00	$ 5,000.00	N
Arctic Grayling Recovery Program	$ -	$ 5,000.00	$ 5,000.00	N
Western Native Trout Initiative	$ -	$ 3,000.00	$ 3,000.00	N
TOTALS	$ -	$ 61,708.00	$ 61,708.00	

February 5, 2015

Elk Springs Creek Geomorphic Reconnaissance Report

Photo 1: Old MacDonald Pond bed- Elk Springs Creek with beaver dam, photo date: 10/09/14.

Prepared by:
Point Bar Resources, LLC
DeWitt Dominick, *Principal Geomorphologist*
PO Box 356
Clyde Park, MT 59018

Prepared for:
Bill West: U.S. Fish and Wildlife Service
Matthew Jaeger: Montana Dept. Fish, Wildlife and Parks
Red Rocks Lakes National Wildlife Refuge
Centennial Valley, Montana

Background

The following report serves as a geomorphic assessment and summary of findings on Elk Springs Creek, located in the northeastern corner of Red Rock Lakes National Wildlife Refuge (NWR), Centennial Valley, MT (Figure 1). The project reach includes approximately 3,500 feet of Elk Springs Creek corridor and the former MacDonald Pond bottom- and newly formed vegetated floodplain. To develop more waterfowl open water habitat, the majority of the creek's historic drainage course was impounded by an earthen dam in 1954, forming MacDonald Pond. To expand potential Arctic grayling habitat, population, and range, specifically to restore suitable spawning habitat, a Montana Species of Concern, and a federal ESA candidate species, the NWR drained the main pond in fall 2009. In 2010, a second impoundment structure "Buck Pond" was removed to drain the upper portion of the waterbody. Finally, in 2011, the Culver Road culvert crossing was removed from Elk Springs Creek channel, which further dropped the channel bed elevation and re-established marginal fluvial conditions upstream towards the springs' source. In response to this effort over the last five years, the channel has narrowed considerably from a former 100- to 500- ft. wide pond to a 25-35 foot wide spring channel where native sedge, forbs, and willow continue to expand, re-colonize, and narrow the channel, forming a wetlands meadow/riparian shrub complex. Despite this recent channel evolutionary response and rapid channel narrowing, the volume and depth of fine-grained lake deposits (silt-fine sand) accumulated for over 55 years pose considerable challenges to restore Arctic grayling spawning habitat through the MacDonald Pond reach.

In summary, this field geomorphic assessment and incipient motion analysis offers the following.

- Rapid channel narrowing and floodplain development (riparian wetlands colonization) occurred in the first several years of post-pond drainage. Given local gradients, depth of lake deposit substrate stored in the channel, and a stable spring creek hydrology, it is unlikely the channel will continue to narrow considerably. The channel is likely close to a new equilibrium when not influenced by beaver activity, subsequent backwater effects, and out of bank flooding.
- The current channel morphology and hydrologic regime is capable of mobilizing the dominant bed load, fine-grained lake bed substrate; however; the channel is only moving it around within the active channel and significant flushing of the fines downstream, and gravel entrainment is not probable.
- Use of flushing flows or flow augmentation from the old Culver Pond ditch would not provide sufficient stream power to entrain spawning sized gravel substrate.
- The historic culvert outlet at MacDonald Pond is not posing a grade imbalance, or artificially holding the channel bed gradient at a higher elevation. The culvert outlet does not appear to be a fish passage issue or hindering sediment transport at the current flow rate. Beaver dams farther downstream below Picnic Creek appear to be backwatering and elevating the existing water profile below the outlet.
- The upper 1,500 linear feet (LF) of Elk Springs Creek offers the greatest opportunity to restore fluvial Arctic grayling habitat; from its headwaters' confluence to approximately the historic Buck Pond structure. Similar spring creek restoration work suggests this upper segment could be built for $20-22/LF; hence, total construction cost estimate: ($30,000 - 33,000).

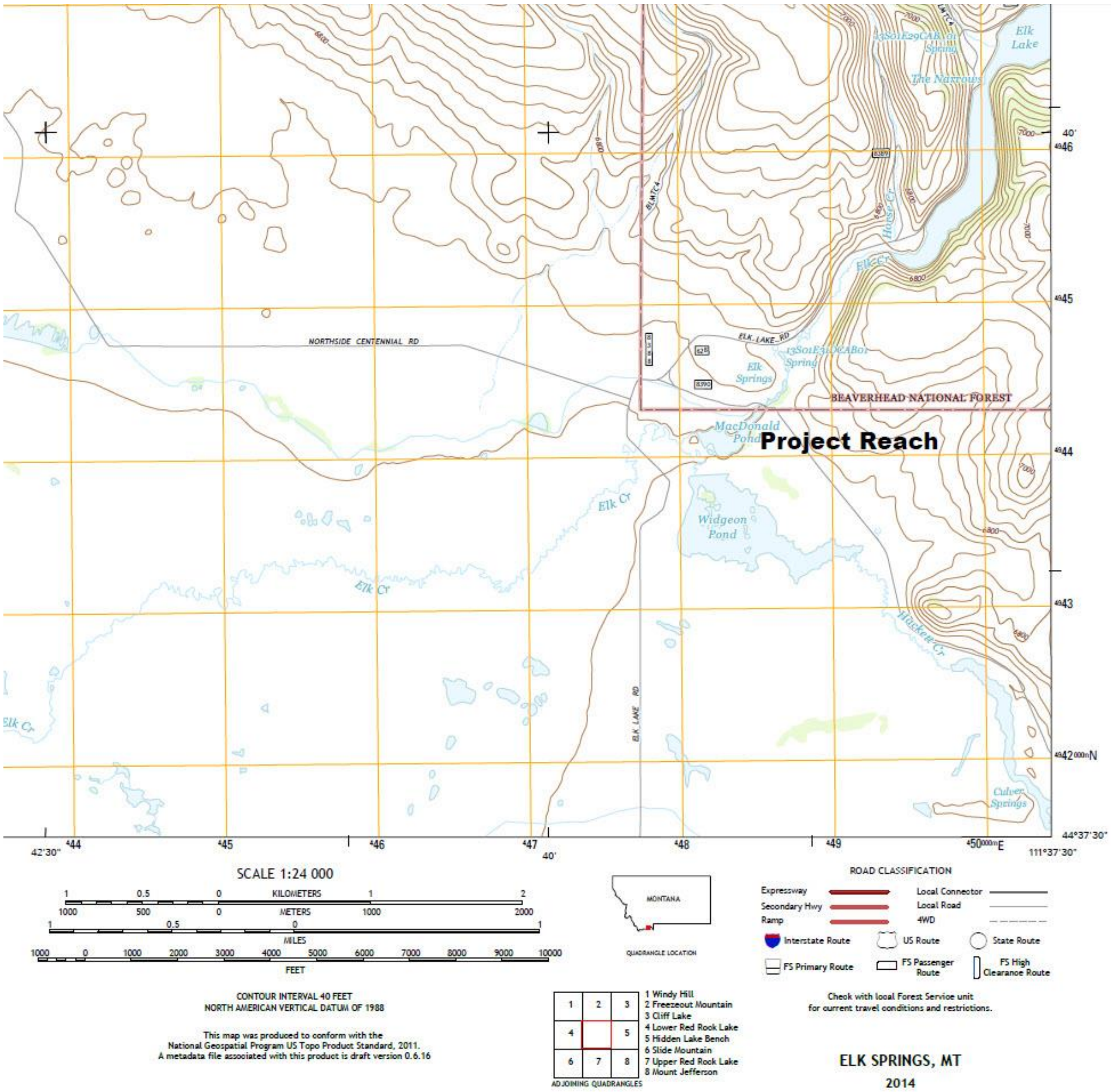


Figure 1. USGS Topo 7.5- minute Elk Springs, MT project location map, legal description: S 1/2 Sec 31, 13 S 1E; and NW1/4 Sec 06 14S 1E.

Geomorphic and Hydrologic Setting

Two separate spring channels of similar flow rates and dimensions surface about 3,000 feet below Elk Lake's southern end. The two threads converge about 650 feet above the old Culver road crossing where the Elk Springs Creek drainage narrows, confined by volcanic bed rock outcropping on either side of the valley bottom. The bedrock here is mafic volcanic rocks (Miocene and Oligocene), a basalt, dark-gray to black, dense, fine-grained flow rock, commonly vesicular or columnar jointed (Figure 2). Much of the contributing Elk Springs watershed area is Huckleberry Ridge Tuff (Thr), consolidated volcanic ash associated with the Island Park Caldera. The exposed gravels visible above the Culver Road crossing towards the head of the spring appear to be mostly this local Tertiary basalt rock, with 1 to 1.5- feet of the fine sand to silt lake bed deposits overlying the gravels. Much of the gravel composition upstream is indicative of the stable low energy spring flow environment, and the relatively young geologic age of the drainage. The bed material is characterized by a veneer of rounded to poorly rounded gravels, with some larger platy-like cobble sized alluvium-colluvium substrate. However, a suitable gradation and volume of spawning gravels appears present above the historic Culver Road crossing.

The valley bottom adjacent to the Elk Springs Creek drainage is surrounded by land features formed by modern Holocene and Pleistocene alluvial-fluvial (Qal), lacustrine (Qlk), and alluvial fan (Qaf) deposits, and a large Eolian sand deposit (Qe) to the northwest. These features and local geology are natural sources of fine-grained sediments; sand-silt, clay underlain by basin fill deposits, and accumulated in the historic MacDonald Pond, and current Elk Springs Creek channel.

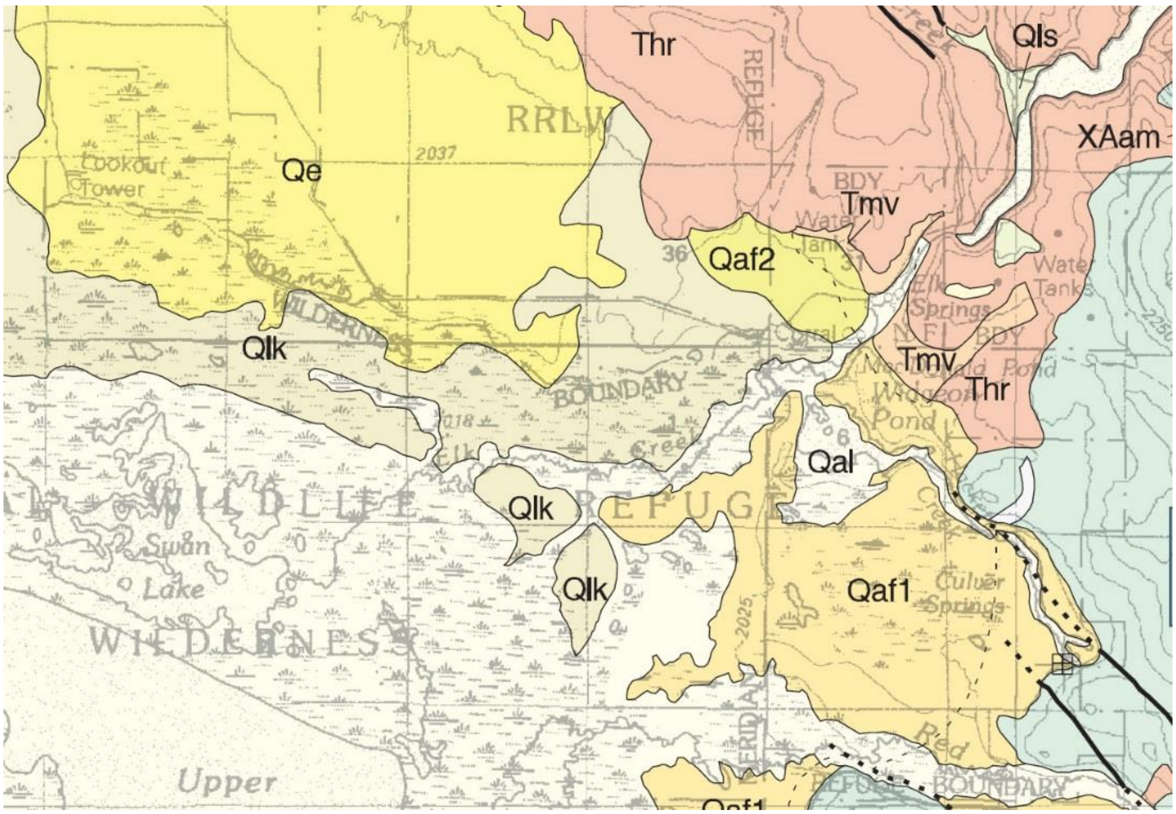


Figure 2. Geologic map of Elk Springs Creek project reach and surrounding area (O'Neill and Christiansen, 2002).

Figure 3. Elk Springs Creek with channel centerline and relative stations in feet. Aerial photo imagery shown here is Year 2011, prior to the removal of the Culver Road crossing.

Field Methods

A geomorphic reconnaissance of the project reach evaluated existing (October, 2014) fluvial geomorphic characteristics and the channel evolution –response to recent management changes, MacDonald Pond draining and subsequent base level changes. A cloth tape and rod-laser level equipment were used to gather necessary data to quantify channel parameters: channel segment lengths, gradient, and geometry. A ½ diameter 3.5-foot soil probe with a 'corkscrew' end was used in an attempt to measure the relative depth of fine-grain lake deposits, a silt-sand substrate. This information was also used to conduct an incipient motion analyses to determine the likelihood of sediment transport of the lacustrine deposits, and continued channel narrowing-vegetation encroachment.

Hydrology

A Marsh-McBirney Flow-Mate 2000 was used to measure flow velocity and estimate discharge following standard USGS procedures. The flow measurement was taken at the upper end of the project reach, the historic Culver Road culvert crossing, approximately. Sta. 27+50, Figure 3. Here, the existing channel is artificially confined, narrowed by the former road embankment and remnant riprap, which offered the most reliable and consistent flow profile through the project reach. The flow rate October 9, 2014 was estimated as 8.9 cubic feet per second (cfs). Upper Elk Springs Creek surveyed cross-sections, local channel bed and energy gradient, and the measured flow rate (8.9 cfs) were evaluated to assess the spring's ability to transport lake bed to spawning sized gravel sediments, and to perform simple incipient motion analyses for both lake bed (silt-sand) and small-medium sized spawning gravels (25 +/- mm).

Channel Hydraulics-Geometry

A longitudinal profile of the stream's water surface and relative bed elevations was surveyed along the upper end of the project reach, including the segment above the old Culver Road crossing towards the headwaters and springs' confluence. Three representative cross-sections were surveyed along the upper half of the project reach. The lowermost section (21+20), while indicative of local channel dimensions, was substantially backwatered from an existing beaver dam (Sta. 7+25), exaggerating total channel dimensions and relative water depth, and flattening the gradient.

Cross-sectional area, wetted perimeter, and hydraulic radius calculated from field measured project sections and energy grade slope(s) were plugged into USACE's Hec-Ras, as well as checked/and re-iterated using Manning's equation, discharge, and Shields relationship (incipient motion) calculation worksheets. A beaver dam near Sta. 7+25 extended across the active channel. The resulting water depth (over 4 feet in channel) prevented this surveyor's ability to wade/access the middle of the project reach. The backwater effect of the beaver dam/pond extended well upstream, inundating the newly forming floodplain willow sedge community at the time of survey (October 8-9, 2014).

The following basic hydraulic relations - incipient motion equations using Shields relationship, between dimensionless shear stress and grain size is recognized as a reliable predictor of initial particle movement/entrainment and sediment transport (Shields (1936);USACE (1995), Andrews (1983).

The total shear stress (bankfull) may be expressed as = $\boldsymbol{\tau_{\circ} = \gamma RS}$ where:

γ = unit weight of water (62.4 lb/$ft^{3)}$;

R = hydraulic radius = A/P; Area ft^2 / wetted perimeter (P) ft

S = energy grade slope (ft/ft)

The critical shear stress, for stability of a particle having a diameter, d_s, may then be calculated from the following equation:

Where critical shear stress = $\boldsymbol{\tau_c = \tau^*(\gamma_s - \gamma_f)\, d_s}$

d_s = particle diameter; γ_s = particle specific weight; and γ_f = fluid specific weight

and critical dimensionless shear stress (Shields, 1936): $\tau^* = \tau/(\gamma_s - \gamma_f)d_s$ is a function of the particle Reynolds number, R*, which is equal to:

$R^* = u_* d_s / v$

where u_* is the shear velocity and v is the kinematic viscosity of water.

Comparing the values of total shear stress of a channel to the critical shear stress for a given particle diameter (d_s) allows one to estimate whether or not sediment transport (incipient motion) would occur, and if so to what extent.

If total shear ≥ critical shear then substrate is mobile; if total shear ≤ critical shear then substrate is immobile.

Results

Preliminary aerial photograph analysis and interpretation of 2010 through 2014 Google Earth imagery and field observations indicate initial channel narrowing occurred rapidly, within the first two years of pond draining and base level changes. Sequential years of incremental dam and culvert removals, and base level change associated with upper Buck Pond drainage, and then the Culver Road culvert decommission, contributed to a dynamic and rapid channel morphologic response to changes in the availability (source), entrainment, and re-deposition of lake bed deposits. Year 2012 imagery indicates multiple channel threads. By 2014, the channel appears more as a single thread with a robust sedge and young willow shrub community encroaching upon the active channel. Many sub-channel-floodplain details were likely inundated by the recent beaver dam and backwater pond during the field site visit in October 2014, which also prohibited direct survey of the middle segment.

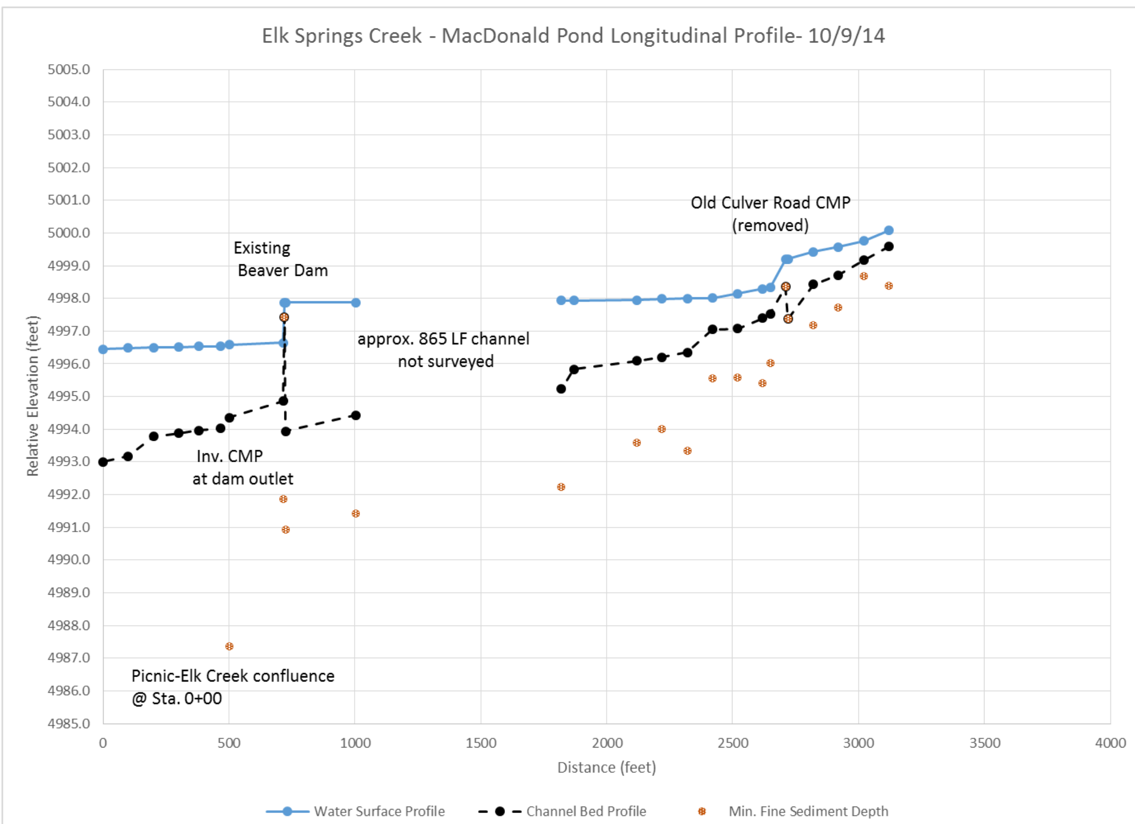


Figure 4. Longitudinal profile of Elk Spring Creek and approximate depth of lake bed deposits in the historic MacDonald Pond. If depth of lake bed deposits exceeded 3 feet, the maximum useable length of soil probe tool, then shown here at 3- foot depth; however may be greater than 3 feet.

Note existing beaver dam and backwater at Sta. 7+15 extends over 1,000 feet upstream. Likewise, additional beaver dams on the main channel downstream of Picnic Creek confluence and Elk Lake Road crossing are causing backwater effects upstream towards the MacDonald Pond outlet (Sta.5+00); thus further flattening the energy grade.

A substantial volume of fine-grained sediment (less than 2 mm caliber) is stored within the active Elk Springs Creek wetted channel at varying depths. The majority of the former ponded area and the lake deposits are now a growing medium for a stable riparian-wetland community adjacent to the active channel; thereby effectively stabilizing or tying up the lacustrine deposits. Assuming historic MacDonald Pond was 16 acres, with an average lake bed deposit of 2 feet, then there would be over 50,000 cubic yards of fine material potentially stored behind the historic impoundments. Attempts to probe or find a gravel substrate outside the immediate active channel; for example, on the new floodplain did not reveal any hard substrate or cementation within a 3- foot depth, the length of the hand soil probe.

The active channel has exposed pockets of gravel where local channel hydraulics and physical complexity supports limited sorting in the upper 1,000 feet of the project reach. The active channel dimensions devoid of beaver dam influences and backwater, are currently on the order of 25-35 feet wide with an average depth of 1.0 feet. A summary of existing geomorphic and hydraulic parameters for the upper reaches of Elk Springs Creek through the old MacDonald Pond bed are presented in Table 1. Incipient motion analyses indicates the existing channel(s) configurations, despite and overall very low gradient typical of spring creeks (0.0020 to 0.0007 ft/ft), and the current flow regime of 8.9 cfs, is capable of transporting the dominant fine-grained silt and sand substrate. The upper 1,000 feet of the channel indicates a veneer of fine- to medium-sized gravels is present (2- 50 mm), and persists overlain by a 1- to 1.5- ft. deposit of historic lake bed sediments (silt to coarse sand). The channel is capable of transporting the fine-grained deposits; however, current channel morphology and flow rate would not induce gravel entrainment without further channel narrowing and deepening.

A substantial volume of fine-grained substrate remain as in-channel storage. As an example, the majority of the lake bed soil probing revealed fines in excess of 3 feet, except in segments of the upper 1,000 feet of Elk Springs Creek channel. Of particular concern was the apparent 'bottomless' depth of fines above the historic MacDonald Pond outlet. Here, (Station 5+25) the survey rod sunk over 7 feet below the existing channel bed (Figure 4). Immediately above the dam, the relative depth of lake bed sediment may be a result of groundwater-surface upwelling and/or dredging occurred here to build the earthen dam, and would also likely have been the deepest part of the historic pond / reservoir.

Table 1. Summary of Elk Springs Creek channel -hydraulic parameters at a measured flow rate of 8.9 cfs (10/9/14)

Station No.	EG Slope (ft/ft)	Channel Width (ft)	Avg. channel Depth (ft)	Channel Area (sq. ft)	Wetted Perimeter ft	Hydaulic Radius ft.	Total Bed Shear Stress (lbs/sq ft)	*Critical Shear Stess (lbs/sq ft) 2 mm	**Critical Shear Stess (lbs/sq ft) 25 mm	Dimension-less Shear Stress
21+20	0.0007	35	1.60	50.8	35.6	1.43	0.062	0.024	0.295	0.035
25+20	0.0007	25	0.60	19.24	25.46	0.76	0.033	0.026	0.320	0.038
29+20	0.0022	30	0.90	26.58	32.03	0.83	0.114	0.022	0.269	0.032

**for coarse sand (2 mm particles)*
*** for gravel (25 mm particles)*

As shown in the Table 1, the calculated total bed shear for all sections is sufficient to entrain and transport fine-grained (silt- sand particles; < 2 mm); however, the current channel dimensions and slope will not mobilize gravel-sized particles (25 mm). The bed shear stress values necessary to entrain gravel are by order of magnitude greater than existing hydraulic conditions.

10/9/2014									
XS1									
Distance (ft)	H rod	HI =	5004.57						
		BF =	4998.15						
0	5.50	4999.07	0.92						
5	6.05	4998.52	0.37						
15	6.35	4998.22	0.07						
35	6.36	4998.21	0.06						
45.5	6.42	4998.15	0.00						
46	6.58	4997.99	-0.16						
48	7.39	4997.18	-0.97						
54	7.40	4997.17	-0.98						
60	7.10	4997.47	-0.68						
66	7.20	4997.37	-0.78						
70	7.00	4997.57	-0.58						
70.5	6.42	4998.15	0.00						
80	6.48	4998.09	-0.06						
100	6.28	4998.29	0.14						
118	5.62	4998.95	0.80						
126	4.60	4999.97	1.82						
	6.42	4998.15	H20 S						
	Where:	Slope (S)	Area (A)	Wetted Perimter (P)		Hydraulic Radius R		Particle (diam)	
								mm	ft
		0.002	19.24	25.46		0.76		2.00	0.0066
total ch shear		0.094				accel. of gravity ***g***		32.2	ft/s^2
						shear velocity u*		0.220605	
						kinematic viscocity		0.000174	ft^2/s
dimensionless *			0.040	0.038	0.030				
						Re =	8.319209		
critical bed shear			0.027	0.026	0.020				

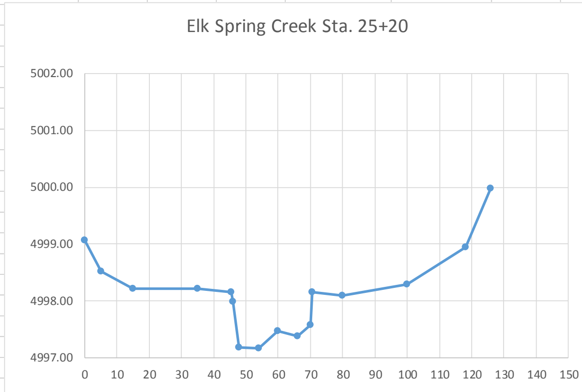
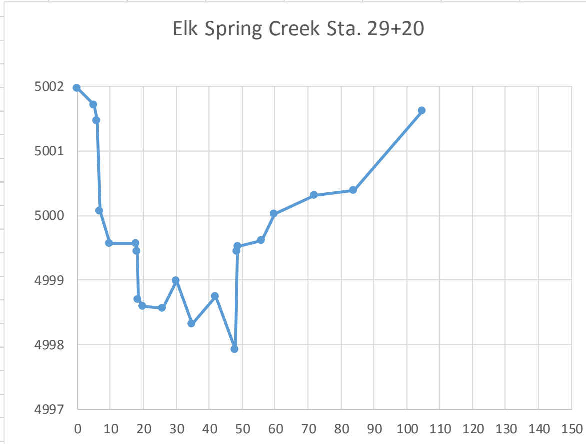


Photo 2. Looking downstream Elk Springs Creek from former Culver Road crossing at typical channel configuration through the upper reach (Sta. 25+20 approx. middle photo).

10/9/2014			
Dist. (ft)	H rod	HI =	5004.57
		BF	4999.45
0	2.6	5001.97	2.52
5	2.85	5001.72	2.27
6	3.1	5001.47	2.02
7	4.5	5000.07	0.62
10	5	4999.57	0.12
18	5	4999.57	0.12
18.25	5.12	4999.45	0
18.5	5.86	4998.71	-0.74
20	5.98	4998.59	-0.86
26	6	4998.57	-0.88
30	5.58	4998.99	-0.46
35	6.24	4998.33	-1.12
42	5.82	4998.75	-0.7
48	6.65	4997.92	-1.53
48.5	5.12	4999.45	0
49	5.05	4999.52	0.07
56	4.95	4999.62	0.17
60	4.55	5000.02	0.57
72	4.25	5000.32	0.87
84	4.18	5000.39	0.94
105	2.95	5001.62	2.17
	5.12	4999.45	H20 S



	Where:	Slope	Area (A)	Wetted Perimter (P)		Hydraulic Radius R		Particle (diam)	
								mm	ft
		0.0022	26.58	32.03		0.83		2.00	0.0066
total ch shear		0.114				accel. of gravity g		32.2	ft/s^2
						shear velocity u*		0.242459	
						kinematic viscosity		0.000174	ft^2/s
dimensionless shear		0.040	0.035	0.032					
						Re =	9.143		
critical bed shear		0.027	0.024	0.022					

Photo 3. Looking upstream from Culver Road crossing towards spring source and typical channel morphology (Sta. 29+20) with 1- ft veneer of lake deposits- historic upper pond footprint.

Photo 4. Typical shallow deposits of 0.5 to 2.0- inch diameter gravel substrate found upstream of Culver Road crossing and downstream of the springs' source.

Tables 2. Elk Spring Creek 25 ft. wide channel template; stage-discharge relation- estimated hydraulics, and flow rate. Use of Manning's equation estimates that over 175 cfs would be necessary to mobilize gravels at a 2.5 ft. depth. Current channel geometry and slope does not support this scenario.

Elk Spring Creek Centennial Valley, MT Red Rock Lakes NWR											
Top Width = 25 feet											
Bed Material	mm	ft		mm	ft		Shields	Param =	0.03		
D_{50} =	2	0.007	D_{100} =	25	0.082						
	AREA	**Wetted Perim**	**R**		**SLOPE**		**VAVG**	**Q**	**τ**	**τ_{cD50}**	**τ_{cD100}**
STAGE	**(ft^2)**	**(ft)**	**ft**			**n**	**(ft/s)**	**(cfs)**	**(lb/ft^2)**	**(lb/ft^2)**	**(lb/ft^2)**
0.1	1.965	19.861	0.099		0.002	0.035	0.407	0.800	0.012	0.020	0.253
0.2	3.960	20.221	0.196		0.002	0.035	0.642	2.542	0.024	0.020	0.253
0.3	5.985	20.582	0.291		0.002	0.035	0.836	5.001	0.036	0.020	0.253
0.4	8.040	20.942	0.384		0.002	0.035	1.006	8.086	0.048	0.020	0.253
0.5	10.125	21.303	0.475		0.002	0.035	1.160	11.740	0.059	0.020	0.253
0.6	12.240	21.663	0.565		0.002	0.035	1.301	15.926	0.071	0.020	0.253
0.7	14.385	22.024	0.653		0.002	0.035	1.433	20.617	0.082	0.020	0.253
0.8	16.560	22.384	0.740		0.002	0.035	1.557	25.789	0.092	0.020	0.253
0.9	18.765	22.745	0.825		0.002	0.035	1.675	31.426	0.103	0.020	0.253
1	21.000	23.106	0.909		0.002	0.035	1.786	37.514	0.113	0.020	0.253
1.1	23.265	23.466	0.991		0.002	0.035	1.893	44.040	0.124	0.020	0.253
1.2	25.560	23.827	1.073		0.002	0.035	1.995	50.995	0.134	0.020	0.253
1.3	27.885	24.187	1.153		0.002	0.035	2.093	58.371	0.144	0.020	0.253
1.4	30.240	24.548	1.232		0.002	0.035	2.188	66.160	0.154	0.020	0.253
1.5	32.625	24.908	1.310		0.002	0.035	2.279	74.357	0.163	0.020	0.253
1.6	35.040	25.269	1.387		0.002	0.035	2.367	82.956	0.173	0.020	0.253
1.7	37.485	25.629	1.463		0.002	0.035	2.453	91.954	0.183	0.020	0.253
1.8	39.960	25.990	1.538		0.002	0.035	2.536	101.346	0.192	0.020	0.253
1.9	42.465	26.351	1.612		0.002	0.035	2.617	111.128	0.201	0.020	0.253
2	45.000	26.711	1.685		0.002	0.035	2.696	121.300	0.210	0.020	0.253
2.1	47.565	27.072	1.757		0.002	0.035	2.772	131.857	0.219	0.020	0.253
2.2	50.160	27.432	1.829		0.002	0.035	2.847	142.798	0.228	0.020	0.253
2.3	52.785	27.793	1.899		0.002	0.035	2.920	154.121	0.237	0.020	0.253
2.4	55.440	28.153	1.969		0.002	0.035	2.991	165.826	0.246	0.020	0.253
2.5	58.125	28.514	2.038		0.002	0.035	3.061	177.910	0.254	0.020	0.253

Table 2 shows a stage-discharge relationship and relative hydraulic properties of a channel template with a 25 feet wide bank top width and slope of 0.002 (ft/ft), ***n*** roughness value of 0.035, and a Shields parameter of 0.03. Note the highlighted rows (yellow) show where stage (depth) reaches approximately 9.0 cfs, and the estimated forces and flows (Q) necessary to move 2 mm (D_{50}) and 25 mm (D_{100}) particles, respectively. While flushing flows may initiate greater mobilization of fine-grained substrate, there is no realistic scenario to mobilize and sort spawning gravels with the existing channel slope and geometry.

Discussion and Management Recommendations

The natural recruitment and colonization of native sedge and willow has contributed to short-term channel narrowing and a new channel equilibrium, which includes entrainment and transport of the lake bed deposits (< 2 mm). On the upper 1,500 feet of the project reach, a veneer of small- to mid-sized gravel deposits are available within the active channel. Likewise, the natural valley-drainage slope is greatest in the upper reach as the creek is more confined by upland features and bedrock outcrop towards the foothills and spring's sources. The upper portion of the project reach (Sta. 20+00 -35+00) offers the greatest potential for restoring Arctic fluvial grayling habitat.

No Action

No action- wait another 5 years and continue to survey-monitor channel dimensions. Further explore historic alignment; pursue a more accurate and comprehensive method to sample (core) historic lake bed and channel profile to determine if gravels persist at a restorable depth for spawning habitat in the lower reaches.

Riparian-wetland recruitment and encroachment has stabilized and tied up lacustrine sediments, which otherwise would remain a major sediment source along the new channel bank margins. With a stable spring flow rate around 9.0 cfs, Elk Springs Creek hydraulics under the existing channel dimensions cannot readily entrain spawning sized gravels. Portions of the channel will continue to narrow, but a much slower rate. The relative depth and mass volume of fine material stored in the channel will likely limit quality spawning habitat to the upper project reach where gravels are already visible and local gradients are greatest. If indeed spawning sized gravels are overlain by lake bed sediments in the lower half of the project reach, the channel cannot physically access the gravel by down cutting to a lower bed elevation because the gradient is not available. If there are no gravels in proximity to the new channel bed, it is unlikely the former MacDonald Pond footprint will provide ample grayling spawning habitat without mechanical restoration of the channel

Mechanical Restoration

Mechanical restoration offers the benefit of immediate channel narrowing and deepening (lower width to depth ratio) to a geometry and slope that better produces higher flow velocity, physical complexity, and the option to introduce spawning sized gravel substrates where necessary. The old Culver Road crossing and the remnant riprap segment is the steepest of the entire project reach (Sta. 26+00 to 28+00). Utilizing this 1- foot drop over a longer restored channel segment would greatly improve future hydraulics and spawning habitat through this upper reach.

The results of the field reconnaissance, data collection, and incipient motion-geomorphic analyses offer the following observations with regards to future management opportunities and recommendations.

- The existing channel configuration is capable of mobilizing the fine-grained sediment as in – channel storage, but incapable of mobilizing and sorting spawning sized gravels.

- Given the extremely low gradient of the valley bottom (ancient Pleistocene Lake) and spring creek corridor, a flushing flow rate from Culver Pond would not be adequate to evacuate the lake bed substrate and entrain gravels.
- Under the existing 25-35 ft. channel geometry and slope, a flow rate of over 175 cfs would be required to entrain 1- inch (25 mm) gravel sized particles. Flow augmentation from Culver Pond to sort spawning gravels and flush lake bed deposits is not a viable management option.
- The uppermost 1,500 linear feet of the Elk Springs Creek channel to the springs' sources offers the greatest opportunity to mechanically restore quality Arctic grayling habitat as this segment shows evidence of spawning sized gravel substrate overlain by 1- to 2- feet of lake bed deposits.
- This upper reach also offers the most gradient through the project reach with the over steepened Culver Road crossing historic riprap channel segment (Figure 4); this grade drop could be spread over a longer profile to help restore quality spawning habitat.
- Based on similar scale spring creek restoration projects, a preliminary cost estimate to restore the upper 1,500 LF of Elk Springs Creek through mechanical restoration: *1,500 LF @ $20-22/LF = $30,000-$33,000.*

Literature Cited

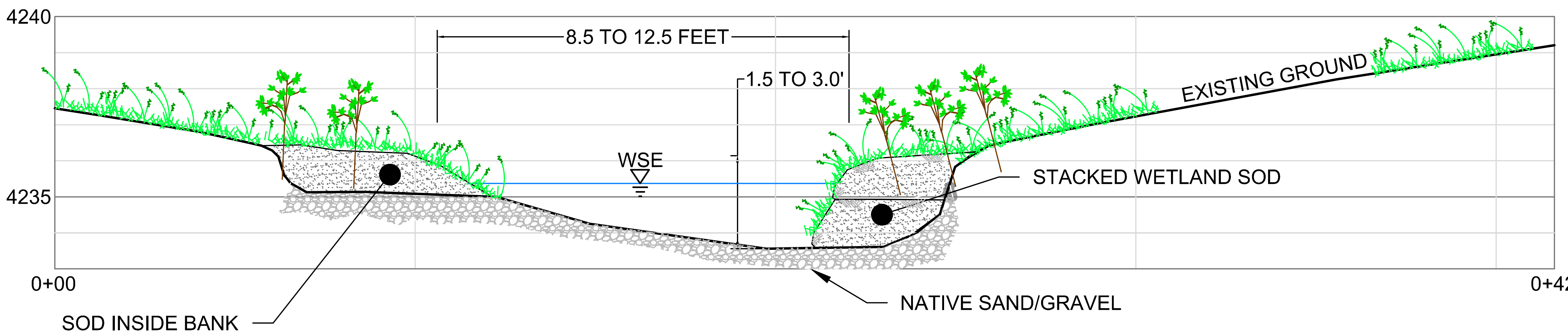
Andrews, E. D.1983. Entrainment of gravel from naturally sorted riverbed material. Geological Society of America Bulletin. V. 94. P. 1225-1231.

O'Neill, J. M. and R. L. Christiansen. 2002. Geologic map of the Hebgen Lake 30' x 60' Quadrangle, Beaverhead, Madison, and Gallatin Counties, Montana, Park and Teton Counties, Wyoming, and Clark and Fremont Counties, Idaho. Montana Bureau of Mines and Geology, Open File Report 464.

Shields, A. 1936. Andwendung der Aehnlichkeitsmechanik und der Turbulenzforschung auf die Geschiebebewegung, Mitt Preuss. Versuchsanst. Berlin. Wasserbau Schiffbau, 26, 26. Application of similarity principles and turbulence research to bed-load movement. (English translation by W. P. Ott and J. C. van Uchelen, 36 pp., U.S. Dep. Of Agric. Soil Conser. Serv. Coop Lab., California Institute of Technology, Pasadena, 1936).

United States Army Corps of Engineers, 1989. Sedimentation investigations of rivers and reservoirs. Office of the Chief of Engineers, Engineers Manual No. 1110-2-4000. Washington D. C.

TYPICAL STACKED SOD BANK POOL TREATMENT



Notes:

1. Treatment applies to pool habitats
2. The lower bank will be constructed in lifts using a combination of live willow cuttings backfilled and compacted with sand/gravel.
3. Upper banks will be constructed by placing sod on the prepared bank toe
4. As available willow transplants and willow plantings will be integrated into the bank

SHEET C6

POOL CROSS SECTION TREATMENT
ELK SPRINGS CREEK RESTORATION

RED ROCK LAKES NATIONAL WILDLIFE REFUGE
BEAVERHEAD COUNTY, MONTANA

DATE: 1/15/2016
CHKD:
DRAWN: TC
PROJ. No.: 101-15

POINT BAR RESOURCES, LLC
PO BOX 356
CLYDE PARK, MT 59018
(406)-223-7600

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